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Treatment Systems for Household Water Supplies: Reverse Osmosis

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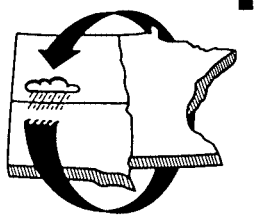

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Impurities Removed by Reverse Osmosis

Reverse osmosis (RO) has become a common method for the treatment of household drinking water supplies. Effectiveness of RO units depends on initial levels of contamination and water pressure.

RO treatment may be used to reduce the levels of:

- Naturally occurring substances that cause water supplies to be unhealthy or unappealing (foul tastes, smells or colors).
- Substances that have contaminated the water supply resulting in possible adverse health effects or decreased desirability.

RO systems typically are used to reduce the levels of total dissolved solids and suspended matter. In South Dakota, the principle uses of reverse osmosis are for the reduction of high levels of nitrate, sulfate, sodium and total dissolved solids.

RO units with carbon filters also may reduce the level of some man-made chemicals like pesticides, dioxins and VOCs (volatile organic compounds like chloroform and petrochemicals). An RO unit alone may not be the best solution for these types of contaminants, but installing a properly designed RO unit to reduce the levels of other contaminants may provide a reduction in SOCs and VOCs.

How to Test Your Water

Before installing any water treatment system, be sure to have the water tested. The test will identify the bacteria and level of minerals present. Interpretation of the test results will help determine whether treatment is needed and what type of system or systems to consider. The intended use of the water (drinking only, drinking and cooking, laundry, or all household uses) also helps determine the type and extent of treatment needed and the type of system to select.

Note: RO systems normally are used to treat only drinking and cooking water supplies so may not be preferred where larger quantities are being treated. RO systems are not appropriate for treating water supplies that are contaminated by coliform bacteria.

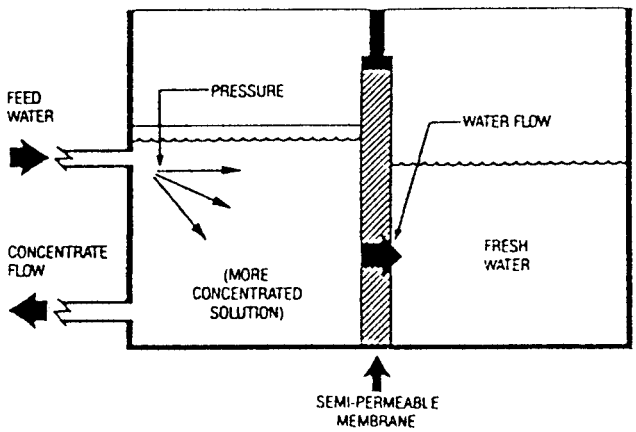
The water test analysis and interpretation will provide information about both naturally-occurring substances and those resulting from human activity.

Treatment of contaminated water supplies should be considered only as a temporary solution. The best solution is to remove the source(s) of contamination and/or obtain a new water supply.

How Reverse Osmosis Works

RO sometimes is referred to as ultrafiltration because it involves the movement of water through a membrane (Figure 1). The membrane has microscopic openings that allow water molecules, but not larger compounds, to pass through. Some RO membranes also have an electrical charge that helps reject some chemicals at the membrane surface. Proper maintenance is essential to retain effectiveness over time. Some units are equipped with automatic membrane flushing systems to clean the membrane.

Figure 1. Dynamic cross-section of a reverse osmosis unit.



Measuring RO Effectiveness

The effectiveness of RO units is characterized by the rejection rate or rejection percentage. The rejection rate is the percent of a contaminant that does not move through, or is rejected by, the membrane. Some typical rejection rates for common contaminants are shown in Table 1. These rejection rates are for single contaminants under design conditions.

Where water contains more than one contaminant, the rejection rate for each contaminant may be reduced or one of the contaminants may be reduced in preference to the other contaminant. For example, cases have been reported where water supplies containing either high TDS levels or high sulfates in combination with nitrates show no decrease in nitrates after treatment. (Nitrates as used in this publication refers to nitrate-nitrogen or NO_3^-N.)

Rejection rates need to be high enough to reduce the contaminant level in the untreated water to a safe level. To determine the needed rejection rate, it is necessary to consider the initial concentration. For example, if a water supply contains nitrates at a concentration of 20 milligrams per liter (mg/l), an RO unit rejecting at a rate of 85 percent, which means 15 percent remaining, would reduce the level to 3 mg/l (20 times 0.15 = 3).

Water with very high levels of nitrates (such as 100 mg/l) would remain near or above health standard levels even after treatment. Nitrate levels this high are not expected in this region and indicate unusual problems that require special investigation and handling. The National Sanitation Foundation (NSF) recommends that special designs be used for RO units where the NO_3^-N level exceeds 40 mg/l.

Table 1. Typical rejection rates for common contaminants.

Contaminant	Rejection Rate Range*	
	Laboratory Tests	Field Tests
Nitrates	83 - 92 %	** - 92 %
Total dissolved solids	95 - 99 %	60 - 99 %
Sulfates	90 - 98 %	60 - 98 %
Sodium	87 - 93 %	60 - 93 %

* These values are for properly maintained units. Poorly maintained units will not be as effective at removing contaminants and, in the worst care, may not be removing any contaminants.

Disadvantages of Reverse Osmosis Units

RO units use a lot of water. They recover only 5 to 15 percent of the water entering the system. The remainder is discharged as waste water. Because waste water carries with it the rejected contaminants, methods to recover this water are not practical for household systems. Waste water typically is connected to the house drains and will add to the load on the household septic system. An RO unit delivering 5 gallons of treated water per day may discharge 40 to 90 gallons of waste water per day to the septic system.

Equipment in an RO System

A typical home reverse osmosis treatment system is shown in Figure 2. The system normally is located beneath the kitchen sink since it is used to treat water for drinking and cooking purposes. RO systems consist of the prefilter, RO membrane unit, a pressurized storage tank for the treated water, a post-filter, and a separate delivery tap for the treated water supply.

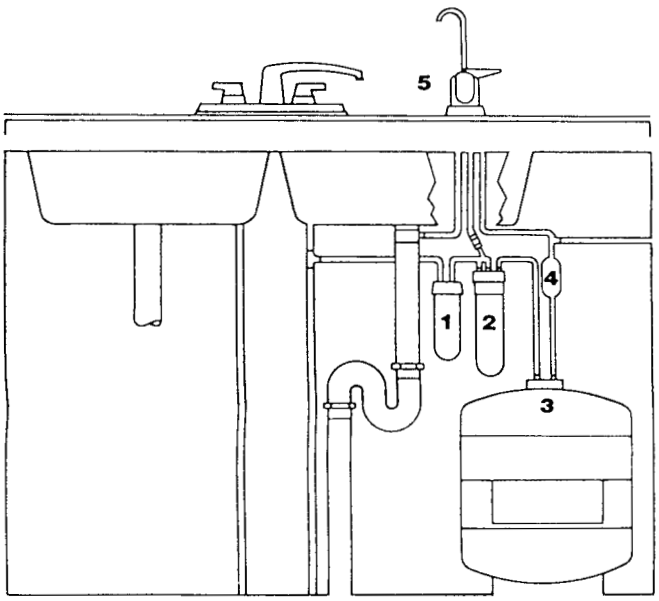
The water supply entering the RO unit should be bacteriologically safe. RO units will remove virtually all microorganisms, but they are not recommended for that use because of the possibility of contamination pinhole leaks or deterioration due to bacterial growth.

Prefilter: The prefilter is sometimes referred to as a sediment filter. It removes small suspended particles to extend the life of the membrane. Some membrane units are damaged by chlorine and others by bacterial growth. An inline activated carbon prefilter is recommended when chlorine is present.

RO Membrane: Several kinds of reverse osmosis membranes are available. The most common materials are cellulose acetate or polyamide resins. Mixtures or variations of these materials also are used. Each product has certain advantages and limitations and these need to be considered carefully. Investigate these factors:

- The contaminant(s) involved and their initial concentration(s).
- The water supply rate or whether the system will deliver enough water to meet normal, daily drinking and cooking requirements.
- The rejection rate, or the percentage of contaminants to be removed by the membrane.

Figure 2. A typical home RO system includes: (1) particle filter, (2) reverse osmosis membrane unit, (3) pressurized treated-water storage, (4) carbon adsorption post-filter, and (5) separate treated-water tap.



- The water pressure required to meet the supply and rejection rates. That is, can this unit be operated on the normal operating pressure of a home water system or will a booster pump be required?
- How can the system's performance be monitored? That is, how can leaks or other problems be detected or how is the time for servicing or replacement determined? Some systems have built-in monitors, but many do not. Conductivity meters, pressure gauges, and other devices can be used to detect problems where monitors are not included. Where coliform bacteria or other special contaminants are a known or suspected problem, periodic testing is recommended.

Storage Tank: Most RO units supply treated water at very low rates so a storage tank of 2 to 5 gallons is used to provide a suitable supply. These units are pressurized to produce an adequate flow when the tap is open. Under-sink storage requires minimum pressure to deliver water. Other locations may require increased delivery pressure which may reduce membrane performance.

Post-Filter: The main reason for postfiltration is to remove any residual organics from the treated water. Usually, a carbon filter is used for this purpose. Where a carbon filter is used as a part of the prefiltration step, postfiltration is normally eliminated.

Delivery Tap: A separate delivery tap for the treated water is used so that both treated and untreated water are available.

Other: No special controls are required on most systems since they operate by the use of pressure-sensitive switches, check valves, or flexible bladders. Shut-off valves are important to conserve water during low use periods. Monitoring gauges or servicing lights are becoming increasingly common and assist greatly in knowing whether the system is or isn't working.

Cost of an RO System

When deciding on a water treatment system, be sure to investigate all options and all costs. To compare purchase to lease or rent options, consider the following:

Initial costs of the system: Be sure that all parts are included, especially when comparisons are being made. RO units range in cost from $300 to $3000 and vary in quality and effectiveness. Replacement membranes cost $100 to $200 and filter cartridges around $50.

Installation costs: These costs are generally the responsibility of the purchaser, but who pays installation fees when renting or leasing? Is there enough space to accommodate the system being considered or will some modifications of space be needed?

Operating and maintenance costs: Electricity to pump the water is the only significant operating cost. Filter cleaning and/or replacement (both pre- and post-filters) and RO membrane replacement need to be estimated. Whether routine maintenance can be done by the owner or requires special service is important information when purchasing a system. When renting or leasing, how and when servicing is to be done and who pays for the supplies and service needs to be clearly stated. For example, is the service done on a schedule or an as needed basis?

Summary

Reverse osmosis is a proven technology that has been used successfully on a commercial basis. Household RO units typically deliver small amounts (2 to 10 gallons per day) of treated water and waste 3 to 20 times the amount of water treated.

Reverse osmosis units remove many inorganic contaminants from household drinking water supplies. The removal effectiveness depends on the contaminant and its concentration, the membrane selected, the water

pressure, and proper installation. RO units require regular maintenance and monitoring to perform satisfactorily over an extended period of time.

Before purchasing an RO unit or any other water treatment equipment, test your water to be certain that treatment is needed and that the equipment being selected is appropriate to the problem requiring treatment.

Consider all costs when comparing competitive systems and when making purchase or rental decisions.

Further Information

Contact your local county Extension Office or state health department. Additional information is available in other publications in the *Treatment Systems for Household Water Supplies* fact sheet series:

FS 877A Activated Carbon Filtration
FS 877C Chlorination
FS 877D Distillation
FS 877IM Iron and ManganeseRemoval
FS 877S Softening
FS 877P Identifying and Correcting Water Problems

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